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Code Of Best Practice for C^2 Assessment

Analyst's Summary Guide

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A DoD CCRP/NATO Collaboration

This major revision to the Code of Best Practice for C2 Assessment is the product of a NATO Research and Technology Organisation (RTO) sponsored Research Group (SAS-026). It represents over a decade of work by many of the best analysts from the NATO countries. A symposium (SAS-039) was hosted by the NATO Consultation Command Control Agency (NC3A) and provided the venue for a rigorous peer review of this code.

This publication is the latest in a series produced by the Command and Control Research Program (CCRP) under the auspices of the Assistant Secretary of Defense (C3I). The CCRP has demonstrated the importance of having a research program focused on the national security implications of the Information Age. The research sponsored and encouraged by the CCRP contributes to the development of the theoretical foundations necessary to support the Information Age transformation of the Department. Other CCRP initiatives are designed to acquaint military and civilian leaders with emerging issues related to transformation. This CCRP Publication Series is a key element of this effort.

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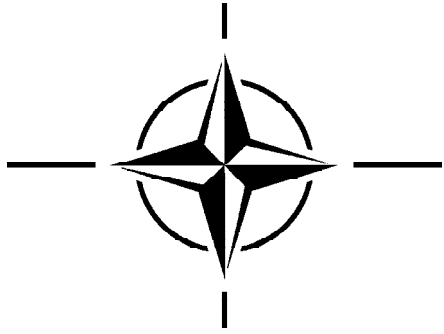

NATO Code of Best Practice for C2 Assessment

Analyst's Summary Guide

NATO CODE OF BEST PRACTICE FOR C2 ASSESSMENT

Analyst's Summary Guide

Introduction

Background and Aims

NATO has produced a Code of Best Practice (COBP)[1] in order to facilitate high quality assessment in the area of Command and Control (C2). The COBP is the product of international collaboration drawing together the operational and analytical experience of leading military and civilian defence experts from across the NATO nations. The COBP enhances the understanding of best practice and outlines a structured process for the conduct of operational analysis for C2, which is the core capability of Information Age defence and security.

The command and control aspects of military capability are difficult to assess. Use of the COBP will increase the likelihood of quality products that

are complete, relevant, transparent, credible, and authoritative. In particular, the COBP will:

- Support broadening of the analysis process;
- Support effective use of analysis in direct support of operations;
- Improve the quality and coherence of business cases;
- Reduce risk and cost of the planning, preparation, analysis and presentation of supporting documentation;
- Provide a methodology acceptable to both analysts and decisionmakers.

The COBP facilitates effective structuring of the analytic process. It describes a framework that can be used to design, execute, review, and deliver high quality C2 assessments that include all key factors and stakeholders. Use of the COBP should be regarded as a community standard for all levels and scales of assessment studies.

Definition of C2

C2 has been defined by NATO as Military Function 01: "The Organisation, Process, Procedures, and Systems necessary to allow timely political and military decisionmaking and to enable military commanders to direct and control military forces."[2] C2 systems are further defined in NATO documents to include: headquarters facilities, communications, information systems, and sensors & warning installations.[3] More recently, the term *C2* has referred to the collaborative

and consultative processes that are an inherent part of coalition operations.

For the purposes of the COBP, the term *C2* is intended to be an umbrella term that encompasses the concepts, issues, organisations, activities, processes, and systems associated with the NATO definition of C2 as well as the other terms enumerated above.

Why is C2 Special?

C2 is special because it explicitly involves representation of the human component. The focus of military research and analysis has predominantly been on the physical domain. C2 deals with distributed teams of humans operating under stress and in a variety of other operating conditions. C2 problems are thus dominated by their information, behavioral, and cognitive aspects, which have been less well researched and understood. This focus creates a multidimensional, complex analytic space that involves multi-sided dynamics including friendly, adversary, and other actors, action-reaction dynamics, and tightly coupled interactions among elements such as doctrine, concepts of operations, training, materiel, and personnel.

C2 issues are difficult to decompose and recompose without committing errors of logic. Moreover, the composition rules by which the various factors inherent to C2 interact are poorly understood except in arenas that have been previously studied in detail. Finally, the C2 arena is weakly bounded, with issues that, although on

initial examination appear quite finite, often prove to be linked to very high-level factors.

The COBP is intended to assist the community in dealing with, and overcoming, the barriers to effective C2 assessment.

Structure of the Guide

The rest of this guide is structured to follow the chapters of the COBP and abstracts definitions, principles, and key points of guidance.

Preparing for Success: Assessment Participants, Relationships, and Dynamics

The issues associated with assessment participants, relationships, and dynamics must be addressed in order to establish a sound foundation for a successful assessment. As an initial step, the individuals who are involved in the study must be identified, the relationships among the participants must be understood, and a common understanding of the study's goals, objectives, scope, and administrative aspects (e.g., schedule, budget) must be established and documented. An assessment team must be assembled that manifests the necessary skills and experience, and the broad plan of attack must be formulated.

Assessment Participants

Early in the study, the assessment team should identify which individuals and organisations should perform key roles in the assessment. The roles of interest include, *inter alia,* assessment team members, decisionmakers or problem owners, stakeholders, bill payers, existing and future study teams, peer reviewers, data providers, assumption providers, and data collectors. It is prudent for the assessment team to map the roles onto the individuals and organisations involved and to understand their interrelationships.

Relationships Among Participants and the Conduct of the Assessment

The relationship among the assessment team, the key sponsor, and the stakeholders is of paramount importance and will influence the course and success of the effort. The assessment team should be aware that the diverse participants may have divergent perspectives and agendas.

The assessment team should undertake the following actions:

- Maintain long-term relationships (including an ongoing dialogue) with the sponsor and stakeholder organisations. This will yield substantial dividends in the form of easier communication, greater trust, and stronger support.
- Generate a concise, agreed-to Terms of Reference, covering goals, scope, products, schedule, and resources.

- Find out at an early stage in the project what the products of the study are to be used for by the sponsor and stakeholder organisations.
- Early in the study, agree on a common language and develop a study glossary. This should evolve during the course of the study.
- Perform a rapid first pass of all the phases of the project to help establish the approximate budget requirements, especially in large C2 projects. The assessment team should establish strategies to address shortfalls in the event the sponsor's resources are limited to a level below what is required to support a quality study.

Assessment Team

- The precise skills and experience required by the assessment team must be established following initial problem formulation. The assessment team must be interdisciplinary.
- As an illustration, the following are representative skills and experience needed for the core team and consultants and part-time team members for a recent, complex C2 assessment:
    - Core Team: project management; OR/OA skills; cross military experience; human science and organistational theory; data collection.
    - Consultants and Part-time Team Members: military; training and exercise planning; communications and information systems

expertise; human computer interface expertise; OOTW related issues.

- Sufficient time and a facilitating process should be built into the project plan for the group of individuals to coalesce into a team.

Assessment Process

- The assessment process is non-linear and iterative.
- The assessment team must realize that all of the elements of the C2 assessment are interrelated. Hence Problem Formulation, Solution Strategy, Measures of Merit, Scenarios, Human/Organisational Factors, Models and Tools, Data, and products are all interdependent (See Figure 1).
- Peer review is a necessity, not a luxury.

Problem Formulation

Effective problem formulation is fundamental to the success of all assessments, but particularly in C2 assessment because the issues are often ill-defined and complex, involving many dimensions and a rich context. The assessment team must perform problem formulation carefully and understand its underlying principles. There are principles of problem formulation that apply to C2 assessment in general, some of which are particularly important to C2 assessment for OOTW, in particular. Drawing on these principles, one can characterize the problem formulation process and

the products that are to be produced in the problem formulation phase.

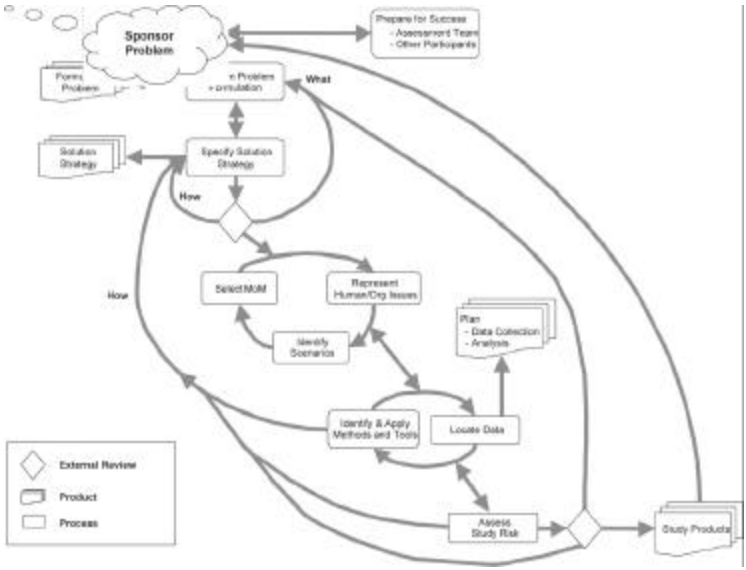

Figure 1. C2 Assessment Process

Definition of Problem Formulation

- Problem formulation is an iterative process that evolves over the course of the study. Iteration is essential even for small studies or where time is short—it will save time later and help ensure quality.
- Problem Formulation is fundamentally a social process of developing a shared understanding.
- The context of the study includes geopolitical context; political, social, historical, economic, geographic, technological environments; actors; threats; aims and objectives of the assessment,

including the decisions to be supported; generic C2 issues; relevant previous studies; and stakeholders and their organizational affiliations.

- The aspects of the problem include issues to be addressed; assumptions; high-level Measures of Merit (MoM); independent variables (controllable and uncontrollable); constraints on the values of the variables (domain and range); time constraints on delivery of advice to the decisionmaker; and whether this is a single decision or (possibly one of) a chain of decisions to be made over time.
- The problem is not formulated until the assessment team has addressed each aspect of the problem.

Principles of Problem Formulation

- Proper problem formulation takes substantial time and effort!
- Explicit problem formulation must precede construction of concepts for assessment or method selection.
- The assessment team must have an understanding of the decisions to be supported by the assessment and the viewpoints of the various stakeholders to clarify the study issues.
- Problem formulation must not only provide problem segments amenable to analysis, but also a clear and valid mechanism for meaningful

synthesis to provide coherent knowledge about the original, larger problem.

- Problem formulation must be broad and iterative in nature, accepting the minimum of *a priori* constraints and using methods to encourage creative and multi-disciplinary thinking.
- The problem formulation process should not focus prematurely on subsets of the problem.
- Practical constraints such as data availability, study resources (including time), and limitations of tools should be treated as modifiers of the problem formulation rather than initial drivers. Such constraints may, in the end, drive the feasible solutions, but it is important to recognise this as a compromise rather than an ideal.
- Problem formulation should address risk from multiple perspectives. Risk analysis techniques should be used to directly explore options to mitigate risk.

Principles Particularly Appropriate for OOTW C2 Assessments

- Problem formulation must address the geopolitical context of the OOTW problem and seek to identify the “broad” C2 issues contained within the Terms of Reference for the study.
- OOTW C2 assessments often involve policy-related impacts outside the context of a particular military operation. Therefore, MoM hierarchies must contain Measures of Policy Effectiveness.

- The assessment team must have an historical perspective to understand OOTW issues because social conflict and structures often have roots far back in history.
- The assessment team must have access to subject matter experts from a broad range of disciplines (e.g., social scientists, historians, and regional experts in OOTW assessment).

Problem Formulation Process

- The process begins with the sponsor presenting the assessment team with a problem to assess and an articulation of broad constraints.
- During the early stages of problem formulation the assessment team should quickly cover the whole assessment process and produce an initial formulation.
- The assessment team must identify what it perceives as the real issues to address. The team must engage in a dialogue with the key sponsor and stakeholders to get "buy in" for these issues.
- In dealing with fuzzy or uncertain boundaries, the assessment team should explore and understand the significance of each proposed boundary. The assessment team should keep an open mind during the early stages of problem formulation about where the boundaries lie and their dimensional nature.
- While clear definitions and hard conceptual boundaries are ultimately necessary in order to

create a manageable problem space, the assessment team should avoid coming to closure prematurely.

- Identification of high-level MoM should start with ideal measures of the desired benefits before considering what can be practically generated by analysis (the latter may force the use of surrogate MoM, but these must be clearly related to the desired measures).
- The assessment team should identify, develop (if necessary), and apply appropriate tools to support problem formulation. Representative tools and techniques include: techniques for supporting expert elicitation, influence diagrams, causal maps, system dynamics models, and agent-based models.

Problem Formulation Products

An iteration of the problem formulation process can be said to be complete when the following is accomplished and documented: the “real” question to be answered is known; the assumptions have been articulated; and the high level MoM, the independent variables, and the constraints associated with the variables have been identified.

Solution Strategies

The Problem Formulation phase clarified “what” is to be achieved during the assessment. The Solution Strategy phase must transform this understanding into “how” these goals and objectives are to be achieved. Even if the way ahead seems clear, the

articulation of a formal solution strategy is necessary. Thus, the assessment team must understand the definition and principles of the solution strategy, the process by which it is developed, and the products that it produces.

Definitions and Principles

A solution strategy consists of the specification of a set of sequential and parallel analytical steps (documented in the Study Plan), often involving several methodologies and tools. The solution strategy is designed to begin with what is known, and by execution of the specified steps, leads to what one desires to know—an illumination of the issues.

- The Study Plan consists of two inter-related parts—the formulated problem (the What) and the solution strategy (the How).
- The solution strategy should not be designed before an initial pass through the problem formulation process and the problem formulation products are available to the team.
- The assessment team should always remember the inherently iterative nature of the process.

Developing a Solution Strategy

- The solution strategy should strike an artful balance between what the team would like to do and what is possible to do, given the state of the art, available data, tools, schedule, and resources available.

- The team should first elaborate on the measures that are to be evaluated in the study. Using these measures and consideration of human and organizational factors, a conceptual model of the analysis should be developed and refined as data requirements, methods and tools, and scenarios are selected for the analysis.
- Frequently, a solution strategy becomes complex, thereby requiring the team to decompose the problem into parts, each of which requires assessment with its own set of tools.
- Taken together, the solution strategy must include the MoMs, relevant human and organizational factors, specification of scenarios, data collection requirements, and methods and tools to be used in the analysis.

Planning Documents

- The solution strategy is documented in a Study Plan that links the problem formulation and solution strategy together in one plan.
- The Study Plan should be developed in an iterative fashion, applying guidance and feedback received from the study sponsor and the study stakeholders.
- The Study Plan is typically approved and signed by the sponsor (decisionmaker). Often, the Study Plan is supported by a Study Management Plan to guide, manage, and coordinate the efforts of the effort.

- The Study Management Plan may have subordinate plans, to include an Analysis Plan(s), Modeling and Simulation Plan, Data Collection Plan, Configuration Management Plan, Quality Assurance Plan, Review Plan, Deliverable Plan, Security Plan, a Study Risk Register, and Glossary.

Measures of Merit

Definitions

MoM is a generic term to encompass different classes of measures. The measures are defined in hierarchical levels related to each other, each in terms of its own boundary. An orchestrated set of MoMs is typically required for C2 assessments. The COBP has adopted the following hierarchical set MoMs:

- Measures of Policy Effectiveness (MoPE) that focus on policy or societal outcomes (e.g., transition measures, which focus on the progress in the transfer of responsibilities to a follow-on military force or civil agency, and normality indicators which measure the quality of life of the civilian population).
- Measures of Force Effectiveness (MoFE) that focus on how a force performs its mission or the degree to which it meets its objectives (e.g. loss exchange ratios, combat effectiveness, number of targets destroyed and desirable adversary behaviour).
- Measures of C2 Effectiveness (MoCE) that focus on the impact of C2 systems within the

operational context (e.g., time to develop a Course of Action, ability to provide information in required format, impact of information operations, and planned quality).

- Measures of Performance (MoP) that focus on internal system structure, characteristics, and behaviour (e.g., time to recognize an event, correctness of perception and system reliability).
- Dimensional Parameters (DP) that focus on the properties or characteristics inherent in the C2 system (e.g., bandwidth, data access times, cost, and size; characteristics of organization forms, attributes of personnel).

Principles

- A multi-faceted and sometimes multi-phased approach is recommended, as no single measure or methodology exists to satisfactorily assess the overall effectiveness of C2.
- Established objectives for the assessment must directly link to the MoMs.
- Selection of MoMs should consider assumptions, constraints, models, tools, scenarios, other elements of the analytic plan, and assessment processes.
- Identify selected MoMs, their thresholds and standards, their means of collection, their relationship to the assumptions, and their imposed constraints in the assessment.

- A detailed review of reliability and validity for the selected measures will determine a level of confidence for each MoM.
- The analyst must establish and measure control variables to correlate MoMs in a spectrum of multiple scenarios.
- The analyst must pay particular attention to measurements related to the human element, since variations in measurements may well cause unacceptable levels of uncertainty.
- Analysis of uncertainties and measures of central tendency and dispersion are significant for C2 issues.
- For C2 acquisition analyses, measures should be generated in parallel with system development, so they can be used as standards for system tests and operations.

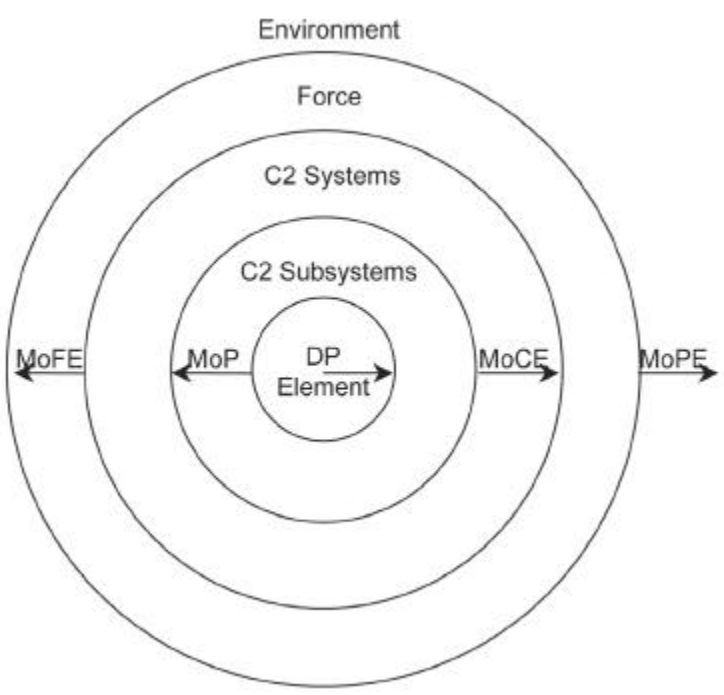

Figure 2. Relationships of Measures of Merit

Human and Organizational Factors

The human dimension largely distinguishes C2 analysis from other military operations analysis. C2 analysis must deal with distributed teams including military, interagency, coalition and other non-state actors operating under stress and their varying decisionmaking behaviours. In OOTW, particular attention must be paid to the behaviour of and interaction with non-military organizations, political groups, and amorphous groups such as crowds and refugees. Thus, the formulation of the problem and the development of solution strategies cannot be

completed without explicit consideration of both human and organization issues.

- Human and organizational factors must be considered as part of structuring the problem, selecting MoMs, defining scenarios, developing solution strategies, and selecting methods and tools, and they should be reviewed throughout the entire analytical process.
- The assessment team must include, or have access to, experts from organizational science and the various human science disciplines (such as cultural anthropology, demography, sociology, social and individual psychology, political science).

Human Factors

Human factors of interest fall into three major categories:

- Human behaviour related to performance degradation and as a consequence of social interaction among individuals or members of a group;
- Decisionmaking behaviour (cognitive questions) including the cognitive complexity of issues and the capacities of the commanders and other decisionmakers of interest;
- Command style.

Human performance depends on psycho-physiological variables (e.g., stress, sleep deprivation, hunger, and alertness) and on ergonomic and external factors. Individual and group behaviour is the result of social processes and factors (e.g., fear, morale, values), and the cultural, educational, and religious background of individuals.

- Any time human performance and/or behaviour are at issue, parameters and/or models are needed to reflect those issues. Unless specialists can provide valid parameters from work in other contexts or from field experience in OOTW, some experimentation may be necessary and appropriate to develop them.
- Decisionmaking that is automatable, contingent, rule, or algorithmically based can be modelled directly, but time requirements and error representation must be incorporated if humans are involved in the actual process.
- Complex decisions (e.g., courses of action in response to events in the operations space) are best being modelled with “human in the loop” techniques. Closed form techniques for modelling complex decisions are still in the experimental stage.
- Accounting for differences in command styles and how they affect military decisionmaking is of special importance in OOTW which tend to be multinational coalition operations. They may be reflected by attributes such as the background of commanders, their field experience, risk attitudes, and organizational and orders style.

Organizational Factors

Organizational design reflects the interaction among the tasks to be done, the people to do them, and the systems and tools that support those people.

The principal differences between organizations are related to structure, function and capacity.

Structural differences include:

- Number of echelons in the command structure;
- The span of control for nodes in the command structure; and
- The pattern of (formal and informal, permanent and transitory) linkages between nodes (hierarchical tree, spokes of a wheel, multi-connected, networked).

Functional differences include:

- The distribution of responsibility (location of functional activities such as, e.g., intelligence, logistics, civil military cooperation (CIMIC);
- The distribution of authority (ideally co-located with responsibility);
- Functional specificity (of combat, support, or service capabilities) versus integrated capabilities (mission tailored task forces); and
- Degree of ambiguity in command relationships.

Capacity differences are related to:

- Personnel (quality, training, experience);
- Information and Communications systems and architectures; and
- C2 field training and operational experience.

A systematic approach using a hypothesis-testing logic and aided by organisation theory expertise should be used for addressing organizational issues in C2 assessment because of the large number and many indirect effects of organizational variables.

Scenarios

Scenarios provide the context for the conduct of the operational analysis and bound the arena of the analysis. Scenarios consist of several static dimensions shown in Table 1 and include the dynamic evolution of events in time. Operational scenarios detail threats, orders of battle, tactics, rules of engagement and courses of action, deployments, reserves, adversary forces, and non-combatants.

Attributes

Several prerequisites are essential before using scenarios for C2 analysis:

- Approval: the analyst should strive for the creation of a family of scenarios consistent with high-level guidance and policy;
- Breadth: scenarios should reflect those factors that are hypothesised to have a significant impact on C2 issues;
- Capability: scenarios should stress C2 capabilities, including human and organisational factors (military and/or civilian) where appropriate;
- Credibility: scenarios should include logical assumptions about the problem under analysis; and

External Factors	**Environment**	**Mission Objectives**	**Mission**
	Economic/Military/ Political/Social/ Historic Situation	Mission Constraints & Limitations ROE	Military Scope Intensity Joint/Combined
	National Security Interests		
Capabilities of Actors	Organisation, Order of Battle, C2, Doctrine, Resources, Lessons Learned, Weapons, Logistics, Skills, Morale		
	Friendly Forces	Adversary Forces	Neutral Forces Non-Combatants
Environment	Geography, Region, Terrain, Climate, Weather, Civil Infrastructure (e.g., Transportation, Telecommunication, Energy)		

Table 1. The Static Dimensions of the Scenario Framework

- Plausibility: scenarios should represent plausible situations.

Principles

- Analysts need to use multiple scenarios and vignettes to cover or sample the interesting problem space since no single scenario is sufficient.
- Analysts should explicitly identify and describe the scenarios prior to the execution of a study. It is best practice to revisit the scenario definition periodically during the conduct of the study.
- For coalition C2 assessments, scenarios should be developed or adapted by teams with representatives from all participating nations.
- Scenarios should reflect C2 organizations and infrastructure (including human issues), processes, and systems relevant to the analysis.
- Scenarios must consider mission scope, levels of hierarchy, and data flow aggregration/disaggregation.
- Key scenario assumptions and constraints should be identified and documented.
- Boundaries of the scenario spaces should be defined by the problem being analyzed.
- Scenarios should reflect the factors that have significant impact on C2, stress C2 issues, are credible to the military, and are credible in terms of civil-military objectives.

Methods and Tools

This section considers the best methods and tools (quantitative or qualitative) for assessing C2 processes, performance and effectiveness. The section covers methods and tools used for analysis, training or operations, each of which has different requirements. Available methods can be categorised into several classes, namely: data collection/ generation, data organisation/relationship, solving and support. Table 2 illustrates this categorisation for a sample of methods.

A key challenge for C2 assessment methods is to make properly quantified linkages between MoP, MoCE, MoFE, and MoPE. All C2 assessments require a high level of creative problem structuring and solving in making these linkages.

Method and Tool Selection

The following issues must be considered when selecting methods and tools for C2 assessments.

- The inherent complexity of C2 assessment problems, which calls for an orchestrated set of complementary tools to cover the wide range of variables involved (including hierarchies or federations of models rather than dealing with all issues in a single model).
- The requirement to explore a wide range of scenarios and still represent C2 processes and performance effectively.

	Data Generation	Data Collection	Data Organization/ Relationship	"Solving"	Support
After Action Reviews and Historical Analysis		•	•		
Expert Elicitation		•			
Constructive and Virtual Simulations	•	•	•		
Exercises/Experiments	•		•		
Game Theory			•	•	
Army C2 Evaluation System (ACCES)		•	•		
Causal Mapping			•		
Multi-Criteria Decision Analysis (MCDA)			•	•	
Regression Analysis			•	•	
Bayesian Networks			•	•	
Mathematical Programming			•	•	
Heuristic Search				•	
Genetic Algorithms	•			•	
Project Management Tools					•
Data Analysis			•		
Geographical Information Systems		•			
Visualization	•				•
Databases			•		•
Checklists		•			

Table 2. Examples of Methods and Tools Categorized by Use

- The appropriate treatment of human issues in models and the balance of realism against possible sources of uncertainty in the use of “human-in-the-loop” techniques.
- The relative advantages of stochastic and deterministic models (depending on the nature of the assessment problem and other elements of the solution approach).
- The appropriate balance for the representation of friendly, adversary and other forces.

- The challenge of VV&A and the development of trust in methods and tools, especially in novel applications areas such as unfamiliar OOTW situations.

Best practice for the application of analysis tools for C2 assessment is still emerging, but the following criteria should be used when selecting models.

- Functionality-based criteria (including resolution, completeness/scope, functionality, explicitness, the ability to generate required MoM, validity, and accreditation).
- Performance-related criteria (including responsiveness, simplicity, preparation/use time, data availability, interoperability with other tools, resource requirements and credibility).

Utility of Different Types of Methods and Tools

- The use of model federations, particularly with an object-oriented approach, encourages development using holistic and evolutionary principles, under which modellers should capture a complete model of the process, including parts whose representation is still unclear (ready for improvement as understanding develops).
- Agent-oriented modelling favours the capture of the cognitive nature of command tasks. This is important in establishing the linkage between MoP and MoFE, but is constrained by the difficulty in representing human performance, command styles and organisational relationships.

- Very fast-running models can be used as screening tools during problem formulation to scan the problem space, allowing identification of areas of concern for deeper analysis.
- The model-test-model or model-exercise-model processes should be considered where the assessment problem requires generation of new data to validate existing models of C2 factors. Assessment teams should be aware of the latest advances in fast, agile modelling and exploit them.

Directions for Future Development

The following ideas should be considered in new model developments (taking account of the appropriate level of model aggregation).

- Understanding of adversary intent can be represented by having a set of prescribed options;
- HQs with a local “picture” in each should be explicitly represented to allow different perception-based behaviours to be represented, facilitating the study of factors such as deception, shock, and surprise;
- Information should be represented as a commodity as follows:
  - a realistic flow of information around the operational environment;
  - the collection of information from multiple sources and the tasking of information collection assets;

- the processing of information;
- C2 systems as entities on the battlespace/ operational space;
- unit perceptions built, updated, and validated from the information available to the unit through its information systems;
- the commander's decision based on the unit's perception of the operational space;
- information operations actions and impacts across all sides represented in the model.

Data, Meta-data, and the Common Data Infrastructure

While the value of data for an individual study effort is well understood by the analytic community at large, the aggregated worth of data is still undervalued by many. Data can be described as the fundamental elements of information and knowledge that comprises the corporate whole - consequently its aggregated value particularly when addressed in a context larger than an individual study is significantly greater than the sum of the parts. Explicitly dealing with this issue resulted in data receiving its own chapter in the code.

Data are factual information organised for analysis.

- The Data Taxonomy in the COBP lays out a number of types of data including broad categories of sources that will be of interest to the analyst. The ability to determine the needed

data and the ability to assemble or collect these data will constrain the solution strategy.

- A major challenge is to find, organise, verify, process, and convert source data into the data needed for the study. The team needs to know (a) what data are needed in which structure; (b) who owns these data; (c) security issues; and (d) costs to buy, collect, or generate data.
- If the data are not available and can neither be aggregated nor derived from the available sources, it is good practice to use the knowledge of subject matter experts to generate the necessary data.

Meta-data are "information about information," which are used to document the data and related issues.

- The source of the data, the reliability, and assorted assumptions and constraints must be captured in standardized meta-data sets assigned to the data sets comprising the needed information.
- Data that are collected without adequate documentation are frequently viewed as suspect or unusable. To avoid having good data thrown away due to the lack of documentation, acceptable community standards for documentation must be employed. This information has to be captured in standardized meta-data sets.
- The initial data available will often be vague, uncertain, incomplete, and contradictory. On the other hand analysts prefer data to be sharp,

certain, complete, and consistent. The assumptions inherent in accomplishing this transformation must be captured in standardized meta-data sets.

A **Common Data Infrastructure** facilitates reuse of data. It is based on agreed standards for data formats, meta-data, and documentation.

- Data are central to the conduct of good assessments. Adhering to data engineering principles contributes to data reuse. Archiving of data in retrievable form using standardized meta-data sets is one essential component to facilitate data reuse.
- As the data being used today by the analysts will be the data needed tomorrow by systems engineers, decisionmakers, and commanders for their operations, it is good practice to align the standardization processes and respective tool sets between the analytical and operational communities in order to facilitate the transfer of data between those communities.

Risk and Uncertainty

Definition

Risk is commonly defined as the possibility of suffering harm or loss. Uncertainty can be defined as an inability to determine a variable or system state or predict its future evolution.

There are risks associated with the uncertainties in decisionmaker's situation that are the subject of the assessment and there are risks related to the conduct of the assessment itself. Using the COBP should help minimise the risks involved in C2 studies, but the following risk and uncertainty issues remain and are intrinsic to any C2 study.

Scope of Risk and Uncertainty

- The explicit treatment of risk and uncertainty is best practice in all studies and of particular importance in C2 assessment. It is advisable not to skip risk analysis, even when time and resources are limited, and this should be stressed to decisionmakers and study sponsors.
- Perceptions of risk and uncertainty can substantially differ from objective assessments and this should be explicitly considered. Analysts should find out how study sponsors perceive risks.
- A thorough understanding of study variables is essential for effective treatment of uncertainty. OOTW studies typically have less well-formed quantitative factors and more qualitative factors.
- The assessment team must be aware of sources of uncertainty in all aspects of a study, including those related to the assumptions and limitations inherent in parameter values, models, scenarios, data structures, and the boundaries used to scope and focus the study. Humans involved in the assessment process make assumptions that should be identified, documented and analysed.

- In C2 assessments, analysts need to be particularly alert to the possibility of chaotic behaviours arising from dynamic interactions of human and organisational factors, and discontinuous, non-linear divergence arising from the multiple options for choice of course of action.

Treatment of Risk and Uncertainty

- Where uncertainties cannot be reduced by acquiring more information, multi-factorial sensitivity analysis should be used to establish the regions for which the results are valid and to isolate those factors that may introduce uncertainty.
- Sensitivity analysis should not only deal with statistical variance but should also consider qualitative variations in models, perspectives and assumptions. A range of analytic tools relevant to sensitivity analysis is identified in the full text of the COBP.
- Checklists and structured appraisal help to maintain study rigour, but neither is a substitute for critical thinking in the specific study context.
- The team should expect a complex and partly hidden set of risks to C2 studies and serious efforts should be made to illuminate them in an explicit risk-based analysis with portfolio-based solutions. Such analysis needs metrics for risk and failure as well as MoMs.
- The assessment team should make a complete list of risks and treat them in appropriate detail in

a risk register for the study. A generic risk register has been produced to support the COBP.

Communication of Risk and Uncertainty

Communication of uncertainty and risk is particularly important for C2 assessment products. Such communication must take account of the complexities of the subject and human limitations in understanding risk and uncertainty.

A continuing dialogue with stakeholders about uncertainty will facilitate common understanding, including the impact of uncertainty on the robustness of conclusions and methods for mitigating them.

Products

Assessment products communicate results to decisionmakers and stakeholders, establish the credibility of the effort, and provide a lasting record of the project. Typical C2 assessment products include the Study Plan, Periodic Status Reports, the Project Journal and a Final Report and Briefing, which include a variety of supporting data and documents.

- The Study Plan, a living document kept current throughout the assessment, explains the problem under analysis, the solution strategy, the tasks involved, and how they fit together. This will include, as appropriate, plans necessary for the assessment, such as data collection and data analysis plans. The elements of a Study Plan are enumerated in the Solution Strategy section.

- Periodic Status Reports describe the state of the effort over time and can be assembled to create a record of the work accomplished, problems encountered, results from peer reviews, and the adjustments made by the team.
- The Project Journal records interactions with professionals outside the core team and captures the analytic assumptions and decisions made by the assessment team (such as choice of tools and selection of data or methods for generating data) over time.
- The Final Report presents the results of the effort (findings, recommendations, and lessons learned) and incorporates, as necessary, items from the other key documents. It will also typically include appendices that provide supporting detail such as participants in the effort, references, glossary, list of acronyms and abbreviations, as well as technical material such as data collection instruments.
- The Final Briefing, which typically is circulated more broadly than the Final Report, will provide a summary of the most important aspects of the project, including the problem statement, solution strategy, research accomplished, findings, recommendations, and lessons learned. Best practice requires that this document be richly annotated.
- Data, models, supporting scenario materials, and other products necessary to make the results credible and authoritative or that may be of value to other researchers or assessment teams

should be archived and made available as broadly as possible.

In general, all the products should be circulated as widely as possible so that others can benefit from the work accomplished and redundant projects avoided. This requires that specific effort be made to downgrade or sanitize products and to identify those who would benefit from reviewing them.

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[1]North Atlantic Treaty Organisation (NATO) *NATO Code of Best Practice for C2 Assessment*, 2002.

[2]North Atlantic Treaty Organisation (NATO) *Annex B to MC Guidance for Defence Planning.* MC-299/5. (1996)

[3]North Atlantic Treaty Organisation (NATO) *Bi-MNC C2 plan part 2—Command and control requirements*. (1998).

ANNEX A

Decisionmaker's Temporal Question List

Attached is a list of questions that have been included in the decisionmakers' guide. It would be prudent if the analyst is prepared to respond to these questions.

This annex contains key questions that a decisionmaker should ask the C2 assessment team. These questions are organized temporally according to the following phases of a study (prior to the study, at initial review, after first iteration, and at final report).

Prior to the Study:

- Do you understand what decisions(s) I have to make, when I have to make them, and the context within which the decision(s) will be made?
- Do you need any information or authorization from me?
- Who will be on the study team?
  - Are there adequate skills, experience present in the team?

  - For OOTW studies in particular, are there adequate social scientific skills in the team?

- Who are the key organizations/individuals with whom you plan to interact (e.g., stakeholders, data providers, review team)?
  - Have you coordinated the Terms of Reference with them?
  - How do you plan to interact with them?
- Particularly for OOTW studies, how will you acquire the requisite knowledge of the culture/ historical context?
- How will you undertake problem formulation? e.g.,
  - What products will you review/mine?
  - What methods and tools are applicable
- When will key events occur (e.g., reviews, production of interim products)?

At the Initial Review:

- What do you perceive the “real” issues to be?
- What assumptions do you plan to make to scope the effort?
- What do you plan to use for
  - High level MoMs?
  - Scenarios of interest?

- Have you identified any additional organizations/ individuals with whom you plan to coordinate?
- How do you plan to attack the problem?
  - What methodology will you employ?
  - How will you treat the diverse aspects of a mission capability package (including concept of operations, organization, doctrine, C2 approach, systems, personnel, facilities, in other words everything needed to field a real capability.)
  - How do you plan to address organization/ human issues?
  - What specific methods and tools will you employ? Why do you think they are appropriate?
- What data will you employ? Where will you get them? Why do you think they are appropriate? How do you plan to make the data accessible to others? How do you plan to depict the results of the study?

At First Iteration:

- What specific MoMs were selected? What relationships were established among the MoMs?
- What range of scenarios were selected? Why?
- What plans do you have to illuminate uncertainty/ sensitivity?

- What feedback did you receive from the independent review team? What steps did you take to respond to it?
- What do you plan to do on subsequent iterations?
    - Use additional tools?
    - Consider additional scenarios, assumptions?
    - Modify assessment boundaries?

At Final Report:

- What are the major findings, recommendations?
- What are the key points of uncertainty/sensitivity?
- What issues were not addressed that should be treated in subsequent assessments?
- What key lessons did you learn with respect to methods, tools, and data?
- What steps are you going to take to disseminate key insights, products to the broader community?
- Are there any voids/issues that warrant further research?